

REMARKS

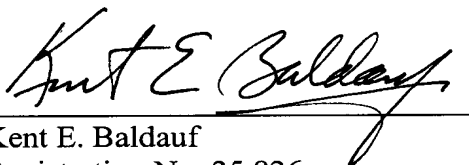
The specification and claims have been amended to place the application in conformance with standard United States patent practice.

Attached hereto is a marked-up version of the changes made to the specification by the current amendment. The attachment is captioned "VERSION WITH MARKINGS TO SHOW CHANGES MADE".

Examination and allowance of pending claims 5-8 are respectfully requested.

Respectfully submitted,

WEBB ZIESENHEIM LOGSDON
ORKIN & HANSON, P.C.

By 

Kent E. Baldauf
Registration No. 25,826
Attorney for Applicants
700 Koppers Building
436 Seventh Avenue
Pittsburgh, PA 15219-1818
Telephone: 412-471-8815
Facsimile: 412-471-4094

VERSION WITH MARKINGS TO SHOW CHANGES MADE

In the specification:

The title has been amended as follows:

[A] HIGH-STRENGTH AUSTENITIC STAINLESS STEEL STRIP HAVING
EXCELLENT [IN] FLATNESS [OF SHAPE] AND [ITS MANUFACTURING]
METHOD OF MANUFACTURING SAME

Paragraph beginning at page 1, line 5 has been amended as follows:

The present invention relates to a high-strength meta-stable austenitic stainless steel strip composed of a dual-phase structure of austenite and martensite exhibiting excellent [in] flatness [of shape] with Vickers hardness of 400 or more[, and]. The invention also relates to a manufacturing method thereof.

Paragraph beginning at page 1, line 10 has been amended as follows:

Martensitic, work-hardened or precipitation-hardened stainless steel has been typically used [so far] as a high-strength material with a Vickers hardness of 400 or more.

Paragraph beginning at page 1, line 12 has been amended as follows:

Martensitic stainless steel such as SUS 410 or SUS420J2 is [material] hardened by quenching from a high-temperature austenitic phase to induce martensite transformation. Since the steel material is adjusted to a Vickers hardness of 400 or more by heat-treatment such as quenching-tempering, its manufacturing process necessitates such the heat-treatment. The steel strip unfavorably reduces its toughness after quenching and changes its shape due to the martensite transformation. These disadvantages put considerable restrictions on manufacturing conditions.

Paragraph beginning at page 1, line 26 has been amended as follows:

Although [a shape] the surface of a steel strip is flattened by cold-rolling, the dependency of hardness on a rolling temperature is [too big] great, and the [shape is irregularly varied] surface flatness varies irregularly along a lengthwise direction or rolling direction of the steel strip. [In this] As a consequence, it is difficult to uniformly flatten [the shape of] the steel strip under stable conditions by cold-rolling from [an industrial] commercial point of view.

Paragraph beginning at page 2, line 2 has been amended as follows:

A degree of transformation from austenite to deformation-induced martensite depends on a rolling temperature, even if a stainless steel strip such as SUS 301 or SUS 304 is cold-rolled at the same reduction ratio. When the steel strip is cold-rolled at a high temperature, generation of the deformation-induced martensite is suppressed, resulting in poor hardness of the cold-rolled steel strip. [A] Conversely, a lower rolling temperature accelerates transformation to deformation-induced martensite and raises hardness of the cold-rolled steel strip[, on the contrary]. [Rising of] Increasing hardness causes an increase of deformation resistance, and so makes it difficult to flatten [the shape of] the steel strip in a uniform manner.

Paragraph beginning at page 2, line 13 has been amended as follows:

The present invention [aims at provision of] provides a high-strength austenitic stainless steel strip exhibiting excellent [in] flatness [of shape] with Vickers hardness of 400 or more. [Improvement of] Improved flatness is attained by a volumetric change during the phase reversion from deformation-induced martensite to austenite so as to suppress shape deterioration caused by martensitic transformation, [instead of] rather than flattening [a shape of] the steel strip while in a martensitic phase [as such].

Paragraph beginning at page 2, line 19 has been amended as follows:

The high-strength austenitic stainless steel strip proposed by the present invention has [the] a composition consisting of C up to 0.20 mass %, Si up to 4.0 mass %, Mn up to 5.0 mass %, 4.0-12.0 mass % Ni, 12.0-20.0 mass % Cr, Mo up to 5.0 mass %, N up to 0.15 mass %, optionally at least one or more of Cu up to 3.0 mass %, Ti up to 0.5 mass %, Nb up to 0.50 mass %, Al up to 0.2 mass %, B up to 0.015 mass %, REM (rare earth metals) up to 0.2 mass %, Y up to 0.2 mass %, Ca up to 0.1 mass % and Mg up to 0.10 mass %, and the balance being Fe [except] plus inevitable impurities with the provision that a value Md(N) defined by the formula (1) is in a range of 0-125.

$$\text{Md(N)}=580-520\text{C}-2\text{Si}-16\text{Mn}-16\text{Cr}-23\text{Ni}-26\text{Cu}-300\text{N}-10\text{Mo} \dots(1)$$

The steel strip has a dual-phase structure of austenite and martensite, which involves a reversed austenitic phase at a ratio more than 3 vol.%.

$$[\text{Md(N)}=580-520\text{C}-2\text{Si}-16\text{Mn}-16\text{Cr}-23\text{Ni}-26\text{Cu}-300\text{N}-10\text{Mo} \dots(1)]$$

Paragraph beginning at page 3, line 1 has been amended as follows:

The newly proposed austenitic stainless steel strip is manufactured as follows:
A stainless steel strip having the properly controlled composition is solution-treated, cold-rolled to generate a deformation-induced martensite phase, and then re-heated at 500-700°C to induce a phase reversion, whereby an austenitic phase is generated at a ratio of 3 vol.% or more in a matrix composed of the deformation-induced martensite. When the steel strip is [reversed in a state charged with] treated in this manner to achieve the austenitic phase reversion of 3 vol.% or more and then placed under a load of 785Pa or more, [it is further improved in flatness of shape] the flatness of the strip is improved.

The section heading beginning at page 3, line 9 has been amended as follows:

DETAILED DESCRIPTION OF THE [PREFERRED EMBODIMENTS]
INVENTION

Paragraph beginning at page 3, line 10 has been amended as follows:

The inventors have researched and examined, from various aspects, effects of conditions for manufacturing a meta-stable austenitic stainless steel strip, which generates deformation-induced martensite during cold-rolling, on hardness and flatness of the steel strip. As [results] a result of the [researches] research, the inventors have found that heat-treatment to promote reversion from deformation-induced martensite to austenite causes a volumetric change of the steel strip which is effective for [improvement of] improving flatness. High strength and excellent flatness are gained by properly controlling the composition of the steel as well as controlling the conditions for reversion. In the specification of the present invention, the wording "a steel strip" of course involves a steel sheet, and the same reversion to austenite is realized during heat-treatment of [the] a steel sheet.

Paragraph beginning at page 3, line 23 has been amended as follows:

C is an austenite former, which hardens a martensite phase and also lowers a reversion temperature. As the reversion temperature [falls down] decreases, reversion to austenite is more easily controlled at a proper ratio suitable for improvement of flatness and hardness. However, precipitation of chromium carbides at grain boundaries is accelerated in a cooling step after solution-treatment or during aging as [increase of] the C content increases. Precipitation of [such the] chromium carbides causes degradation of intergranular corrosion cracking resistance and fatigue strength. In this sense, an upper limit of C content is determined at 0.20 mass %, so as to inhibit

precipitation of chromium carbides by conditions of heat-treatment and a cooling speed.

Paragraph beginning at page 4, line 5 has been amended as follows:

Si is a ferrite former, which dissolves in a martensite matrix, hardens the martensitic phase and improves strength of a cold-rolled steel strip. Si is also effective for age-hardening, since it promotes strain aging during aging-treatment. However, excessive [addition] additions of Si [causes] cause high-temperature cracking and also various troubles [on a] in the manufacturing process, so that an upper limit of the Si content is determined at 4.0 mass %.

Paragraph beginning at page 4, line 12 has been amended as follows:

Mn is effective for suppressing generation of δ -ferrite in a high-temperature zone. An initiating temperature for reversion falls as [increase of] the Mn content increases, so that a ratio of reversed austenite can be controlled with ease. However, excessive addition of Mn above 5.0 mass % unfavorably accelerates generation of deformation-induced martensite during cold-rolling, and makes it impossible to use the reversion for improvement of flatness.

Paragraph beginning at page 4, line 19 has been amended as follows:

Ni inhibits generation of δ -ferrite in a high-temperature zone, [as] the same as Mn, and lowers an initiating temperature for reversion, [as] the same as C. Ni also effectively improves precipitation-hardenability of a steel strip. These effects [are apparently noted] become apparent at a Ni content not less than 4.0 mass %. However, excessive [addition] additions of Ni above 12.0 mass % unfavorably [accelerates] accelerate generation of deformation-induced martensite during cold-rolling and [so] thus makes it difficult to induce the reversion necessary for flattening.

Paragraph beginning at page 4, line 27 has been amended as follows:

Cr is an alloying element used for improvement of corrosion resistance. Corrosion resistance is intentionally improved at a Cr content of 12.0 mass % or more. However, excessive [addition] additions of Cr [causes] cause too much generation of δ -ferrite in a high-temperature zone and requires [increase] the addition of austenite formers such as C, N, Ni, Mn and Cu. [Increase] An increase of the austenite formers stabilizes [an] the austenitic phase at [a] room temperature and makes it [hard] difficult to generate deformation-induced martensite during cold-rolling. As a result, a steel strip after being aged [is] exhibits poor [of] strength. In this sense, an upper limit of Cr content is determined at 20.0 mass %, in order to avoid an increase of the austenite formers.

Paragraph beginning at page 5, line 8 has been amended as follows:

Mo effectively improves corrosion resistance of the steel strip and promotes dispersion of carbides as fine particles during reversion. In reversion treatment useful for flattening [a shape of] a steel strip, a re-heating temperature is determined at a level higher than a temperature for conventional aging treatment. Although elevation of the re-heating temperature accelerates the release of strains, abrupt release of strains is suppressed by the addition of Mo. Mo generates precipitates which are effective [for improvement of] in improving strength during aging [and]. Mo also inhibits a decrease of strength at a reversion temperature higher than a conventional aging temperature. These effects [are apparently noted] become apparent at a Mo content of 1.5 mass % or more. However, excessive [addition] additions of Mo above 5.0 mass % [accelerates] accelerate generation of δ -ferrite in a high-temperature zone.

Paragraph beginning at page 5 line 20 has been amended as follows:

N is an austenite former, which lowers an initiating temperature for reversion, [as] the same as C [does]. Reversed austenite can be controlled at a ratio suitable for flatness [of shape] and strengthening with ease by the addition of N at a proper ratio. However, since an excessive addition of N causes the occurrence of blowholes during casting, an upper limit of N content is determined at 0.15 mass %.

Paragraph beginning at page 5, line 26 has been amended as follows:

Cu is an optional alloying element acting as an austenite former, which lowers an initiating temperature for reversion and promotes age-hardening during reversion. However, excessive [addition] additions of Cu above 3.0 mass % [causes] cause poor hot-workability and the occurrence of cracking.

Paragraph beginning at page 6, line 2 has been amended as follows:

Ti is an optional alloying element, which promotes age-hardening and improves strength during reversion. However, excessive [addition] additions of Ti above 0.50 mass % [causes] cause the occurrence of scratches on [a] the surface of the slab and troubles [on a] in the manufacturing process.

Paragraph beginning at page 6, line 7 has been amended as follows:

Nb is an optional alloying element, which improves strength during reversion but degrades hot-workability of [a] the steel strip. In this sense, Nb content [shall be] is limited to 0.50 mass % or less.

Paragraph beginning at page 6, line 11 has been amended as follows:

Al is an optional alloying element, which serves as a deoxidizing agent in a steel-making step and remarkably reduces type-A inclusions, harmful for press-workability. The effects of Al are saturated at 0.2 mass %, and excessive [addition] additions of Al [causes] cause other troubles such as the occurrence of surface flaws.

Paragraph beginning at page 6, line 16 has been amended as follows:

B is an optional alloying element effective for inhibiting the occurrence of edge cracks, which are derived from a difference of deformation resistance between δ -ferrite and austenite at a hot-rolling temperature, in a hot-rolled steel strip. However, excessive [addition] additions of B above 0.015 mass % [causes] cause generation of low-melting boride and [rather] somewhat deteriorates hot-workability.

Paragraph beginning at page 6, line 25 has been amended as follows:

Each of REM, Y, Ca and Mg is an optional alloying element, which improves hot-workability and oxidation resistance. Such the effects are saturated at 0.2 mass % REM, 0.2 mass % Y, 0.1 mass % Ca and 0.1 mass % Mg, respectively, and excessive [addition] additions of these elements [worsens] worsen the cleanliness of the steel [material].

Paragraph beginning at page 6, line 29 has been amended as follows:

The newly proposed steel strip further includes P, S and O other than the above-mentioned elements. P is an element effective for solution-hardening but harmful for toughness, so that an upper limit of P content is preferably determined at a conventionally allowable level of 0.04 mass %. S content shall be controlled to a lowest possible level, since S is a harmful element which causes occurrence of ear cracks during hot-rolling. The harmful influence of S can be inhibited by addition of B, so that allowable S content is preferably determined at 0.02 mass % or less. O generates nonmetallic oxide inclusions, which worsens the cleanliness of the steel and [put harmful influences on] harms press-workability and bendability[, so that]. Hence, the O content is preferably controlled at a ratio of 0.02 mass % or less.

Paragraph beginning at page 7, line 12 has been amended as follows:

According to the present invention, a shape of a stainless steel strip is flattened by volumetric change during re-heating to induce a phase reversion from deformation-induced martensite, which is generated by cold-rolling, to austenite. For such [the] a reversion, a value Md(N) representing the stability of an austenitic phase against working is controlled in a range of 0-125 so as to generate deformation-induced martensite by cold-rolling after solution-treatment. The value Md(N) shall be not less than 0; otherwise cold-rolling at an extremely lower temperature, which is not adaptable for an industrial manufacturing process, would be necessary for generation of a martensite phase effective for improvement of strength. [If] On the other hand, if the value Md(N) exceeds 125 [on the contrary], an austenitic phase, which is generated during reversion, is re-transformed to martensite during cooling to [a] room temperature, resulting in degradation of shape.

Section heading at page 7, line 24 has been amended as follows:

[A temperature for reversion] Phase reversion temperature: 500-700°C

Paragraph beginning at page 7, line 25 has been amended as follows:

When a solution-treated steel strip is cold-rolled, deformation-induced martensite is generated by [the] cold-rolling. The cold-rolled steel strip is then re-heated at a temperature to reverse the deformation-induced martensite phase to the austenite phase. If the re-heating temperature is lower than 500°C, the phase reversion progresses too slow [in] from an industrial point of view. However, a re-heating temperature higher than 700°C extremely accelerates the phase reversion and also softens [a] the martensite phase, so that it is difficult [to stably bestow the] uniformly provide a steel strip with a Vickers hardness of 400 or more. [The too

higher] An excessively high re-heating temperature also causes degradation of corrosion resistance due to sensitization derived from carbide precipitation.

Paragraph beginning at page 8, line 7 has been amended as follows:

Volumetric change [during] caused by a phase reversion from martensite to austenite [is] results in a dimensional shrinkage of 10% or so, [and] providing a steel strip [is] flattened by [the] shrinkage deformation. Although [a] the shape of [a] the steel strip collapses due to volumetric expansion caused by the transformation from austenite to martensite during cold-rolling, such collapse of the shape is eliminated by the shrinkage deformation during the reversion from deformation-induced martensite to austenite, which is realized by re-heating the cold-rolled steel strip. As a result of the experiments under various conditions, the inventors have found that a ratio of reversed austenite, which effects on flatness of a steel strip, is at least 3 vol.% [at least].

Paragraph beginning at page 8, line 17 has been amended as follows:

A steel strip is held [in a state good of shape] or fixed in a proper, flat state by application of a tension to a strip coil or by gravity of a steel strip itself during reversion. Flatness of the steel strip is further improved by reversion under the condition that a load is applied to the steel strip with a pressboard or the like, since the reversion progresses while the strip is restrained. In this case, a load is preferably of 785Pa or more for each unit area, [accounting] provides high-temperature strength at the reversion.

Paragraph beginning at page 8, line 25 has been amended as follows:

Each stainless steel sample of 250kg having the composition shown in Table 1 was melted in a vacuum furnace, cast to an ingot, forged, hot-rolled to thickness of 4.0mm, annealed 1 minute at 1050°C, and then pickled with an acid. After the steel

strip was cold-rolled, it was re-heated 600 seconds to induce a phase reversion. Conditions for cold-rolling and re-heating are shown in Table 2. In Table 1, stainless steels Nos. 1-8 have compositions which satisfy conditions defined by the present invention, while stainless steels Nos. 9-14 have compositions [out] outside of the present invention. In Table 2 [stainless steels] Example Nos. 1-10 are those processed under conditions according to the present invention, while [stainless steels] Example Nos. 11-19 are those processed under conditions [out] outside of the present invention.

Paragraph beginning at page 12, line 11 has been amended as follows:

Comparative Examples Nos. 14-18 are stainless steel strips, which [was] exhibited poor [of] flatness at Vickers hardness of 400 or more due to alloy compositions out of the range defined by the present invention. Especially, the steel of Example No. 15 was heavily deformed by re-transformation of reversed austenite to martensite during cooling due to a [big] large Md(N) value above 125. The steel of Example No. 19 [involved] exhibited flaws scattered on its surface due to excessive N content, which [originated in] were caused by blowholes originated during the steel making and casting steps [scattered on its surface due to excessive N content].

Paragraph beginning at page 12, line 18 has been amended as follows:

Each steel strip was sized to a sheet of 200mm in width and 300mm in length, formed by cutting off both edges [with] to a width of 10mm, and pressed with a press board at a pressure shown in Table 3 in order to further improve flatness of the steel sheet. The steel sheet was re-heated 600 seconds to induce reversion under the pressed condition. Effects of a load applied to the steel sheet were investigated in relation with flatness of the re-heated steel sheet. Results are shown in Table 3,

together with ratios of reversed austenite and averaged Vickers hardness (a load of 10kg).

Paragraph beginning at page 12, line 26 has been amended as follows:

It is noted from Table 3 that any steel of Example Nos. 1-6 had Vickers hardness of 400 or more in average and height of ears suppressed below 1.0mm due to application of the load during reversion. The relation of the applied load with the maximum height of ears [proves] demonstrates that a shape of a steel sheet is effectively flattened by application of a load of 785Pa or more.

In the abstract:

The section heading beginning at page 18 line 1 has been amended as follows:

ABSTRACT OF THE DISCLOSURE

Paragraph beginning at page 18, line 2 has been amended as follows:

A high-strength austenitic stainless steel strip exhibiting excellent [in] flatness [of shape] with Vickers hardness of 400 or more [is newly proposed, which] has the composition [consisting of] comprising: C up to 0.20 mass %, Si up to 4.0 mass %, Mn up to 5.0 mass %, 4.0-12.0 mass % Ni, 12.0-20.0 mass % Cr, Mo up to 5.0 mass %, N up to 0.15 mass % and the balance being Fe except inevitable impurities [under the condition that] having a value Md(N) in a range of 0-125 defined by the formula [(1) is in a range of 0-125] Md(N)=580-520C-2Si-16Mn-16Cr-23Ni-26Cu-300N-10Mo. [It] The material has a dual-phase structure of austenite and martensite involving a reverse-transformed austenite at a ratio of 3 vol.% or more. [It] The material is manufactured by solution-heating a steel strip having the above composition, cold-rolling the steel strip to generate a deformation-induced martensite,

and then re-heating at 500-700°C to induce a phase reversion from martensite to at least 3 vol.% austenite. The reversion effectively flattens [a shape of] the steel strip.

[Md(N)=580-520C-2Si-16Mn-16Cr-23Ni-26Cu-300N-10Mo⁺⁺⁺(1)]